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National Nanotechnology Investment in the FY 2014 Budget

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Introduction

The emerging fields of nanoscale science, engineering, and technology—which investigate how to measure and restructure matter at the atomic and molecular levels to create materials, devices, and systems with fundamentally new properties and functions — are leading to unprecedented understanding and control over the basic building blocks and properties of all natural and manmade things. The fiscal year (FY) 2014 funding request for nanoscale science, engineering, and technology (in brief, *nanotechnology*) research and development (R&D) is **$1.7 billion** (see Table I-8) across 27 participating federal departments and agencies (see Table 1 for names and acronyms), reflecting nanotechnology potential. Known as the National Nanotechnology Initiative (NNI), this investment began in FY 2001, inspired by a long-term vision,[2] and with a budget of $494 million.[3] The 2011 NNI Strategic Plan and 2011 NNI Environmental, Health and Safety Research Strategy are implementation guiding documents.[3]

The NNI vision is a future in which understanding and control of matter at the nanoscale will lead to a revolution in technology and industry

1 The author is Senior Advisor to the National Science Foundation (NSF) and key architect of the National Nanotechnology Initiative. Opinions expressed in this material do not necessarily reflect the views of the NSF or NSTC.

2 "Nanotechnology Research Directions" (M.C. Roco, S. Williams, P. Alivisatos, eds.), Springer 1999, adopted as an official document of NSTC in 2000; "Nanotechnology Research Directions for Societal Needs in 2020" (M.C. Roco, C. Mirkin, M. Hersam, eds.), Springer, 2011; http://www.wtec.org/nano2/

3 See the NNI website at http://www.nano.gov.

that benefits society. The four goals of the NNI are to: advance a world-class nanotechnology research and development program; foster the transfer of new technologies into products for commercial and public benefit; develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and support responsible development of nanotechnology. The NNI, through the 27 federal departments and agencies, engages in strategic collaboration to accelerate the discovery, development, and deployment of nanotechnology. Because of the NNI, federal agencies have initiated major new nanotechnology R&D activities under a common vision that supports national goals and agency missions. These agencies have established an extensive infrastructure of nanotechnology research and education centers, and they are working together to maximize the effectiveness of their individual and collective investments for societal impacts.

The 21st Century Nanotechnology R&D Act (Public Law 108-153) was signed into law in December 2003 and authorized long-term funding levels for five agencies (NSF, DOE, NASA, NIST, and EPA). New legislation for multi-year reauthorization is currently in preparation in Congress at the time of this writing.

Summary of FY 2014 Budget Request for NNI

The FY 2014 President's request of $1.7 billion for federal investment in nanotechnology is 8.4 percent less than the actual FY 2012 budget of $1.9 billion, mainly because of the decrease in the DOD requested contribution from $426.1 million in 2012 to $216.9 million in 2014. Approximately two-thirds of total NNI funding support academic research and one-third supports R&D at government laboratories and industry. Additionally, about 6 percent of the $1.7 billion budget is estimated for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, based on average funding levels from the five most recent years with completed data, FY 2007 to FY 2011.

NNI-sponsored R&D is reported in eight program component areas (PCAs). The PCAs and proposed FY 2014 funding levels across all NNI agencies are as follows: (1) fundamental nanoscale phenomena and processes, $445 million; (2) nanomaterials, $368 million; (3) nanoscale devices and systems, $400 million; (4) instrumentation research, metrology, and standards for nanotechnology, $57 million; (5) nanomanufacturing, $100 million; (6)

major research facilities and instrumentation acquisition, $176 million; (7) environment, health, and safety, $121 million; and (8) education and societal dimensions, $36 million. While fundamental research remains the largest single NNI investment category, the research on nanodevices and systems and in nanomanufacturing would total more than $500 million. Environmental, health and safety (EHS) would receive about 7.1% of total NNI investment, and is the fastest-growing PCA since 2005. The requested nano-EHS investment in FY 2014 is almost 10% above 2012 actual spending, without accounting for an inflation rate of four percent. Cumulatively, NNI agencies have allocated over $750 million to EHS research since 2005, including the requested amounts in the 2014 budget.

Nanotechnology is partially transitioning its R&D focus from nanoscale components to nanosystems, and from basic research to innovations that support national priorities such as energy, manufacturing, healthcare, and environmental protection (see "Nanotechnology Research Directions for Societal Needs in 2020" (M.C. Roco, C. Mirkin, M. Hersam, eds.), Springer, 2011; available on http://www.wtec.org/nano2/).

Five NNI Signature Initiatives[4] are planned with a total budget of $343 million, an increase of 16 percent over FY 2012 levels of $294 million. These include:

(a) **Sustainable Nanomanufacturing** — $59.8 million with participation from DOD, DOE, IC/DNI, NASA, NIOSH, NIST, NSF, OSHA, and USDA/FS (again, see Table 1 for names and acronyms). This initiative aims to establish manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems, with two areas of focus: design of scalable and sustainable nanomaterials, components, devices, and processes; and nanomanufacturing measurement technologies.

(b) **Nanotechnology for Solar Energy Collection and Conversion** — $102.4 million with participation from DOD, DOE, IC/DNI, NASA, NIST, NSF, and USDA/NIFA. The primary aim of this initiative is to use nanotechnology to improve photovoltaic solar electricity generation, solar thermal energy generation and conversion, and solar-to-fuel conversions.

(c) **Nanoelectronics for 2020 and Beyond** — $79.7 million with

4 http://www.nano.gov/signatureinitiatives

participation from DOD, DOE, IC/DNI, NASA, NIST and NSF. The initiative aims to explore new or alternative "state variables" for computing; merge nanophotonics with nanoelectronics; explore carbon-based nanoelectronics; exploit nanoscale processes and phenomena for quantum information science; and augment the national nanoelectronics research and manufacturing infrastructure network (university-based infrastructure).

(d**) Nanotechnology Knowledge Infrastructure (NKI): Enabling National Leadership in Sustainable Design** — $23.0 million with participation from CPSC, DOD, EPA, FDA, NASA, NIH, NIOSH, NIST, NSF, and OSHA. The initiative aims a community-based, solutions-oriented knowledge infrastructure, including informatics and modeling and simulations, to accelerate nanotechnology discovery and innovation.

(e) **Nanotechnology for Sensors and Sensors for Nanotechnology: Improving and Protecting Health, Safety, and the Environment** — $78.3 million with participation from CPSC, DOD/DTRA, EPA, FDA, NASA, NIH, NIOSH, NIST, NSF, and USDA/NIFA. The initiative aims to provide new solutions in physical, chemical, and biological sensing that enable increased detection sensitivity, specificity, and multifunction in portable devices for a variety of health, safety, and environmental assessments.

The six agencies with the largest investments in FY 2014 are described below.

The focus on energy is reflected in the requested agency increase, with the **Department of Energy (DOE)** request reaching $369.6 million in FY 2014 (see Table I-8). The Department of Energy includes the Office of Science, the Advanced Research Project Agency-Energy (ARPA-E), and the Office of Energy Efficiency and Renewable Energy (EERE). Its focus is on fundamental and applied nanotechnology research providing a basis for new and improved energy technologies. DOE's Office of Science will continue to support full operation of the five DOE Nanoscale Science Research Center user facilities and the Energy Frontier Research Centers. The Office of Science will continue support for the Energy Innovation Hub focusing on batteries and energy storage and Joint Center for Artificial Photosynthesis. The SunShot program within EERE will support a variety of projects that use nanotechnology to drive down the cost of solar power installations.

The National Science Foundation (NSF) will continue to support research and education in all disciplines of nanoscale science and engineering with a budget of $430.9 million in 2014. NSF will support about 5,000 active awards with full or partial contents on nanoscale science and engineering, and about 10,000 students and teachers will be educated and trained. NSF has established a set of three "Nanosystems Engineering Research Centers," which had a total budget of $10 million per year in the summer of 2012 and started the full operation in 2013. The FY 2014 NSF request includes about $125 million for the five Signature Initiatives, an increase of about 1 million over the FY 2012 actual budget. The EHS research will be $29 million, about 7% of the total NNI funding at NSF. Support will be provided to increase research on nanobiology as it relates to predictive toxicity of nanomaterials, and on a new generation of nanotechnology products. Converging science and engineering at the nanoscale work supports the convergence of nanotechnology with information technology, modern biology, and social sciences, potentially reinvigorating discoveries and innovation in almost all areas of the economy.

The Department of Defense (DOD) funding request is $216.9 for FY 2014, approximately 50% lower than FY 2012 actuals of $426.1 million. This reflects the maturation and completion of certain projects, especially at DARPA, and broadly reduced estimates associated with budget uncertainties and ongoing competitions, which cannot be counted until awards are made. The nanotechnology investment will continue with approximately 50% for fundamental research, 40% applied research and 10% advanced technology development. Its focus is on nanoscale science and engineering research advancing defense and dual-use capabilities. A part of investment in nanotechnology is done through the Army Engineer Research and Development Center, the Office of Naval Research's Multidisciplinary University Research Initiative, the Air Force Office of Scientific Research's individual awards, the collaborative Focus Center Research Program at DARPA, the Defense Threat Reduction Agency, the Chemical and Biological Defense Program, and SBIR/STTR programs. An example of basic research includes tailoring the electronic bandgap of graphene using techniques such as catalytic nanolithography, scanning probe and directed e-beam nanolithography, and chemical functionalization. The Navy is exploring extraordinarily lightweight materials with outstanding mechanical properties. The Defense Production Act Title III Program is establishing the infrastructure for the world's first manufacturing production facility for CNT yarn and sheet material.

Another example is development of electrochemical techniques for patterning metals to produce nanoscale features for antennas, sensors, metamaterials, and catalysts.

The Department of Health and Human Services (HHS) would support nanotechnology R&D at about the same level as in FY 2012 ($487.8 million in 2014, an $8.2 million increase) via the National Institutes of Health (NIH: $461.0 million, a $5 million increase), the Food and Drug Administration (FDA: $16.8 million, a $3.2 million increase) and the National Institute for Occupational Safety and Health (NIOSH: $10.0 million, unchanged). NIH has the largest request from all agencies in 2014, to address nanotechnology-based biomedical research at the intersection of life and physical sciences. Research on emerging technologies, projected for 2014, will focus on the translation of nanoscience discoveries into new biomedical technologies. In addition to research on using nanotechnology to deliver new therapies, several of NIH's institutes are focused on advancing nanotechnology-based techniques, including clinical lab tests and assays, and tools and devices, for early disease diagnosis; and *in vivo* imaging techniques. An increased focus will be on building partnerships with the private sector and other NNI agencies. NIOSH will continue to investigate the potential human health hazards of engineered nanomaterials by exploring their biologic mechanisms. There will also be increased emphasis on measuring worker exposures and developing effective control and risk-management methods, along with developing guidance on medical surveillance.

The National Institute of Standards and Technology (NIST) would increase research support in the intramural laboratories and user facilities for nanomanufacturing, major research facilities and instrumentation acquisition, and nano-EHS aspects of nanotechnology. The FY 2014 budget request is for $102.1 million, an increase of $6.7 million over the FY 2012 actual budget. The Center for Nanoscale Science and Technology user facility maintains the capabilities needed to effectively support industrial innovation. NIST will support instrumentation and metrology in all five signature initiatives. Examples of projects include developing the quantitative atom probe, advanced electron and scanning probe microscopy, and optical nanocalorimetry measurement instrumentation needed to advance technologies ranging from semiconductors and data storage to biotechnology and optoelectronics.

NASA'S nanotechnology investment of $17.5 million is $1.1 million

below the FY 2012 actual budget. NASA supports a broad portfolio of research in nanostructured materials and nanotechnology-based sensors and devices. Nanotechnology research is supported by the Aeronautics, Human Exploration and Operations, and Space Technology Mission Directorates. Research in nanostructured materials is focused primarily on the development of lightweight, multifunctional materials for use in aircraft and spacecraft.

A comprehensive infrastructure will continue to be maintained. A list of R&D centers, user facilities and networks, as of April 2013, is given in Table 2 on the following pages.

Many of the NNI participating agencies and programs are also actively participating in and contributing to complementary and synergistic U.S. R&D priorities, including the Networking and Information Technology (NITRD) initiative, the Global Change Research Program, the Materials Genome Initiative, Advanced Manufacturing, and the new Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.

Table 1. NNI members (25 federal departments and agencies)

Federal Agencies Participating in the NNI (March 2010)
Federal agencies (15) with budgets dedicated to nanotechnology research and development
Consumer Product Safety Commission (CPSC)
Department of Homeland Security (DHS)
Department of Commerce (DOC)
National Institute of Standards and Technology (NIST)
Department of Defense (DOD)
Department of Energy (DOE)
Department of Transportation (DOT)
Federal Highway Administration (FHWA)
Environmental Protection Agency (EPA)
Department of Health and Human Services (HHS)
Food and Drug Administration (FDA)
National Institutes of Health (NIH)
National Institute for Occupational Safety and Health (NIOSH)
National Aeronautics and Space Administration (NASA)
National Science Foundation (NSF)
U.S. Department of Agriculture (USDA)
Agricultural Research Service (ARS)
Forest Service (FS)
National Institute of Food and Agriculture (NIFA)
Other participating agencies (12)
Department of Commerce
Bureau of Industry and Security (BIS)
Economic Development Administration (EDA)
U.S. Patent and Trademark Office (USPTO)
Department of Education (DOEd)
Department of Interior (DOI)
U.S. Geological Survey (USGS)
Department of Justice (DOJ)
Department of Labor (DOL)
Occupational Safety and Health Administration (OSHA)
Department of State (DOS)
Department of the Treasury (DOTreas)
Director of National Intelligence (DNI)
Nuclear Regulatory Commission (NRC)
U.S. International Trade Commission (USITC)[1]

1 Non-voting member

Table 2. NNI R&D centers, user facilities, and networks (April 2013).

Name	Institution(s)
NSF – Ten Networks	
National Nanofabrication Infrastructure Network (NNIN) – 15 nodes (user facilities)	Cornell University – main node (under recompetition in 2013)
Network for Computational Nanotechnology (NCN) – 7 nodes (user facilities)	Purdue University – main node
National Nanomanufacturing Network (NNN)	University of Massachusetts, Amherst – main node
Nanotechnology in Society Network (NCN)	Arizona State University and University of California, San Diego
Nanoscale Informal Science Education (NISE) Network	Museum of Science, Boston – main node
Nanoscale Science and Engineering Centers (NSEC)	University of Columbia – main node
Materials Science and Engineering Centers (MRSECs)	Distributed centers
Nanosystems Engineering research Centers (NERC)	Distributed centers
Centers for the Environmental Implications of Nanotechnology (CEIN)	University of California, Los Angeles, and Duke University
Center for National Nanotechnology Applications and Career Knowledge (NACK)	Pennsylvania State University
NSF-Two Science and Technology Centers	
Center for Energy Efficient Electronics Science (nanoelectronics)	University of California, Berkeley
Emergent Behaviors of Integrated Cellular Systems (nanobiotechnology)	MIT
DOE – One Network of Five User Facilities	
Center for Functional Nanomaterials	Brookhaven National Laboratory
Center for Integrated Nanotechnologies	Sandia National Laboratory and Los Alamos National Laboratory
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory
Center for Nanoscale Materials	Argonne National Laboratory
Center for Molecular Foundry	Lawrence Berkeley National Laboratory
NIH – Four networks	
NHLBI Program of Excellence in Nanotechnology	Four distributed centers
Nanomedicine Development Centers	Eight distributed centers
Centers of Cancer Nanotechnology Excellence	Eight distributed centers
Nanotechnology Characterization Laboratory (user facilities)	Frederick, Md. campus
NIST – User Facility	
Center for Nanoscale Science and Technology (CNST), shared-use nanofabrication facility (NanoFab)	Gaithersburg, Md. campus